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ABSTRACT

A persistent problem in aptitude-treatment interaction (ATI) research has been the need for a better conceptualization of instructional treatments. The concerns are important in the analysis of instructional treatments: the importance of considering the psychological processes called upon by the instructional treatment, and the ecological validity or generalizability of the treatment. Gagne suggests eight functions of instruction which describe the situation, involving: motivation objectives; attention, recall or prerequisite knowledge, learning guidance, retention, transfer of training, performance, and feedback. These functions are discussed in relation to questions a researcher might ask under each of two conditions: (1) when selecting aptitudes, given that treatments have already been selected; or (2) when selecting or developing treatments, given that aptitudes have been decided upon. The final system of the paper addresses the benefits that ATI research might derive from studies that examine the functions of instruction. This approach would help ATI researchers focus on the nature of the psychological processes called upon in the treatment situation; narrow the field of relevant aptitudes; and determine relevant outcome and outcome variables. (Author/GDC)

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A FUNCTIONAL APPROACH TO ANALYZING TREATMENTS IN ATI RESEARCH*

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There appears to be no question that aptitude-treatment interactions (ATI) exist in educational settings. Recent and extensive reviews by Berliner and Cahen (1973), Cronbach and Snow (1977), and Snow (1976) provide ample evidence of this fact. However, these researchers and others have pointed out many problems, both theoretical and methodological, that need to be resolved before ATI research can provide meaningful results which also have some promise of practical application. One such problem concerns the analysis of the instructional treatment.

Most researchers who recognize the need for a better conceptualization of instructional treatments focus, either directly or indirectly, on two important concerns in their discussions of this problem. These concerns are (a) the importance of considering the psychological processes called upon by the instructional treatment, and (b) the ecological validity (Bronfenbrenner, 1976; Shulman, 1970) of the treatment. The former concern has received the most direct attention. For example, Glaser (1972) has stated that ". . . treatments investigated in the ATI studies were not generated by any systematic analysis of the kinds of psychological processes called upon in particular instructional methods, and individual differences were not assessed in terms of these processes (p. 316)." Earlier, Cronbach

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(1967) expressed the same concern by suggesting that ATI studies, instead of using hit-or-miss techniques, select promising aptitudes and design treatments to interact with those aptitudes. Kropp, et al. (1967), approached the problem empirically, but limited their concern to one aspect of the treatment, the content dimension. They operationally defined a "form of content" variable and ". . . hypothesized that each variation of form of content can be described in terms of the cognitive aptitudes that are associated with maximal achievement of the content . . . (p. 2)." The concern for relating psychological processes to the analysis, selection, or development of instructional treatments in ATI research has also been expressed by Berliner and Cahen (1973) and Cronbach and Snow (1977).

A notable discordant note in the chorus of support for analyzing treatments in terms of the psychological processes of the learner was sounded by Tobias (1976). While presenting evidence to support the viability of using as an aptitude variable the learner's prior achievement within the content domain, Tobias suggested that the use of task-specific achievement would possibly decrease the importance of laborious analysis of the psychological processes required by the task. He did point out, however, that much research with this approach remains--for example, the development of operational definitions for low and high achievement.

The second issue, that of ecological validity, is a complex one that is central to many of the problems faced by ATI researchers. If ATI research is to produce practical results, problems of generalizability must be resolved. The problem is not one of generalizing to all people in all situations, but rather it is one of determining what results generalize to whom in what situations. Researchers concerned with the ecological validity of ATI

research have called for the design of experiments in which the demand characteristics of the treatment closely approximate the "real-life" environment of the school. Cronbach and Snow (1977), for example, emphasized this point throughout their work. Snow (1976) anticipated the recommendations of Cronbach and Snow for ecologically valid ATI studies by suggesting the ". . . examination of the most plausible ATI hypotheses in large-scale, long-duration, real-school studies {p. 51}." And, Tobias (1976), in expressing concern about the ability of much previous ATI research to generate practical results, suggested that materials used in ATI studies ought to resemble those actually used in the classroom.

The conceptualization of treatments in ATI research from an ecological perspective must of necessity take into account the psychological processes called upon by the treatments. This has been explicitly stated by Doyle (1977) in describing the two-stage process used to derive the propositions of his classroom ecology model. One stage involves specifying the environmental demands of the learning situation and the other involves specifying the mediational strategies needed to meet these demands. The framework for analyzing treatments presented in this paper is consistent with the classroom ecology paradigm of Doyle, with many of Bronfenbrenner's (1976) properties of ecologically valid research, as well as with the views of Cronbach and Snow (1977) and Tobias (1976).

Addressing the apparent need for a better conceptualization of the treatment in ATI research, this paper focuses on an analysis of the treatment from a process perspective. The purpose is to present an approach to analyzing treatments in terms of the functions the treatments are designed to serve. It is hoped that the approach will help ATI researchers determine the demand characteristics of instructional treatments and the psychological

processes activated by the treatments. Specifically, the objectives of the paper are to (a) describe a framework for analyzing instructional treatments in terms of their functions and (b) suggest how this approach to analyzing treatments can further the progress of ATI research.

Functions of Instruction--A Framework

This section describes a framework for analyzing treatments in terms of their functions. The motivation behind the framework comes not only from ATI research, but also from research on teaching, which has experienced many of the same problems as ATI research. For example, Gage (1964) has characterized the use of the term "teaching" as misleadingly generic, because it suggests a unitary activity. In similar fashion, Berliner and Cahen (1973), Cronbach and Snow (1977), and Tobias (1976) have suggested that many ATI researchers may have used the term "instructional treatments" in much the same way. Thus, the failure of many studies to obtain significant aptitude-treatment interactions may have been due to the use of apparently different treatments, like group vs. individualized instruction, which, in fact, differed so slightly that they failed to engage different aptitudes.

The framework herein presented follows from, and addresses, the concerns for the use of ecologically valid treatments, which take into account the psychological processes of the learner. It also follows from Gagné's (1977) conception of analyzing the internal and external conditions necessary for the acquisition of specific learning outcomes. Finally, the framework can be viewed as analogous to, and possibly encompassing, the conceptualization of media suggested by Levie and Dickie (1973) and Salomon and Clark (1977). Thus, according to Levie and Dickie, research on the relationship between

media and instruction can be furthered by (a) specifying media in terms of their attributes, (b) defining media attributes in terms that relate to the ways in which learners process information, and (c) discovering relationships between media attributes and other instructional variables (Levie & Dickie, 1973). For present purposes, it is important to recognize that media attributes can be viewed as capabilities of the media to perform certain functions--for example, to gain the learner's attention.

The approach to analyzing treatments in terms of their functions can be used to accomplish either of two purposes: (a) to select relevant aptitudes, given that the treatments have already been selected or (b) to select or develop treatments, given that aptitudes of interest have been decided upon. In accomplishing either purpose, the ATI researcher must consider the internal conditions relevant to particular learning outcomes and the way these conditions relate to the external conditions within the treatment situation. The internal conditions of the learner include various learned capabilities and information-processing mechanisms, whereas the external conditions include relevant components and processes within the treatment situation. A treatment, then, rather than being a unitary construction, is instead a system designed to accomplish a variety of functions--the external conditions of the instructional system serve to activate the internal conditions within the learner. The functions served by the various components of the treatment enable the ATI researcher to relate internal and external conditions of learning. Gagné (1974) lists the following functions as providing a relatively complete description of the instructional situation:

1. To activate motivation
2. To inform the learner of the objective
3. To direct attention

4. To stimulate recall of prerequisite knowledge and skills
5. To provide learning guidance
6. To enhance retention
7. To promote transfer of learning
8. To elicit performance and provide feedback

Instructional treatments can vary in many ways with respect to the functions they serve. Two treatments, for example, might differ in the way they serve all eight functions, or they might differ with respect to only one or two functions. Treatments may differ not only in the events that serve each function, but also in the sequence of those events. Also, some treatments may include explicit events for only some of the functions; a function like motivating the learner, for example, might be seen as unimportant for an already highly motivated group of learners. When viewed in this way, the functions can be used as a starting point in analyzing or developing instructional treatments in order to ensure a better match between the external conditions of the treatment and the internal conditions of the learner.

By examining the functions of the instructional treatments, researchers can ask a more comprehensive set of questions in designing ATI studies than are often asked about (a) the treatments, (b) relevant aptitudes, and (c) possible outcome measures. The questions below exemplify those a researcher might ask when examining the functions of the instructional treatments.

Selecting Aptitude Variables, Given That Treatments Have Already Been Determined

This situation may become more common as the ecological perspective gains acceptance in research designs and as researchers conduct more investigations

in natural settings. This approach, in which the functions of instruction are examined, suggests several questions related to the instructional treatments; considering these questions and their answers can increase the likelihood of a better match between aptitudes and instructional treatments. The following questions might be asked by an ATI researcher in selecting aptitudes, given that the treatment situation has already been specified.

1. What is the nature of the intended learning outcomes? This question is important because the nature of the intended learning outcomes provides the central link between the relevant learner aptitudes and the events chosen to serve the various functions of instruction. The answer to this question involves specifying the type of outcome to be acquired and the model or theory of the learning process that underlies the acquisition of the intended learning outcome.

Gagné (1977) distinguishes between five types of learning outcomes or learned capabilities--verbal information, intellectual skill, cognitive strategy, attitude, and motor skill. Each learned capability can be distinguished by the processes that take place within the learner and by the external conditions necessary for acquiring the capability. All learned capabilities must be inferred from the behavior of the learner. As an example of what Gagné means by learned capabilities, consider the distinction between verbal information and intellectual skills. In the acquisition of verbal information, the learner might be required to state the names of 19th century British romantic poets, for example. While in the acquisition of an intellectual skill, the learner might be required to demonstrate a rule by classifying 19th century British poems according to romantic or

neoclassical traditions. Acquisition of the intellectual skill goes beyond memorization of facts and implies the ability to use an internalized rule.

For a particular outcome, the researcher should be able to specify the psychological processes involved in acquiring the outcome. The level of specificity should be such that the psychological processes can be related to the external events for each instructional function. (See Figure 1 for an example of the relationship between the psychological processes of the learning task and the functions of instruction.)

After determining the nature of the intended learning outcomes, the researcher can begin speculating on relevant aptitude variables. However, the range of possible aptitudes is likely to be quite large at this point. The two questions that follow will help the researcher narrow the range of possible aptitudes.

2. Given a particular intended learning outcome, which treatment functions are most important in acquiring the outcome? This question is important because different learning outcomes emphasize different psychological processes. For example, the memorization of dates (verbal information), as might occur in a history course, would probably place less emphasis on transfer processes than would the learning of an intellectual skill such as the application of second derivatives to problems in probability theory. In determining the most important treatment functions, the ATI researcher should not examine the nature of the learning outcome in the abstract. Rather, the content domain and the expected range of achievement of the target population with respect to the content domain should be examined. As an illustration of this point, consider the function of stimulating recall of prerequisite skills and knowledge; this function

Figure 1

Relation Between the Psychological Processes of the Learning Task and the Functions of Instruction*

LEARNING PHASE	PSYCHOLOGICAL PROCESSES	FUNCTIONS OF INSTRUCTION
Motivation	Expectancy	1. To activate motivation 2. To inform the learner of the objective
Apprehending	Attention and selective perception	3. To direct attention
Acquisition	Coding and storage entry	4. To stimulate recall of prerequisite knowledge and skills 5. To provide learning guidance
Retention	Memory storage	6. To enhance retention
Recall	Retrieval	
Generalization	Transfer	7. To promote transfer of learning
Performance	Responding	8. To elicit performance and feedback
Feedback	Reinforcement	

*Adapted from Figure 5.8 in Gagné, R. M. Essentials of learning for instruction. Hinsdale, Ill.: The Dryden Press, 1974.

might be fairly important in Algebra II lessons taught immediately following the summer break, but less important for lessons taught later in the year. This conclusion would follow from the cumulative nature of mathematics learning and the assumption that high school students who take Algebra II have mastered most of the basics taught in Algebra I.

After identifying the most relevant treatment functions, the researcher can begin eliminating some aptitude variables from consideration. Any aptitudes that are related to functions not considered important for the intended learning outcomes need not be considered further. The next question allows the researcher to further pinpoint the most relevant aptitudes.

3. Given a particular intended learning outcome, are the functions that are important in acquiring the outcome handled differently by each treatment? In terms of optimizing the potential for finding aptitude-treatment interactions, this question is the critical one. If for each relevant function of instruction the different treatments do not include different events, aptitude-treatment interactions are less likely to be found. At least some of the relevant functions of instruction should be served by different events within each treatment. If enhancing retention and promoting transfer of learning were relevant functions in an ATI study involving a lecture-discussion method and a student-centered method, the researcher would want to ensure that the nature of the teacher-student interactions related to enhancing retention or promoting transfer actually differed in the two instructional methods. For example, the teacher might provide practice in specific examples for transfer to other situations in the lecture-discussion method, while the students might generate their own practice examples in the student-centered method. Although this will not guarantee the finding of aptitude-treatment interactions, it leaves open the possibility.

By the time the researcher gets to this point, (s)he will probably already have identified many potential aptitude variables. The problem becomes one of focusing on those functions for which the different treatments include different events. Then, on the basis of logic, theory, or previous research, the researcher should examine the potential aptitude variables with respect to the different instructional events for each function. Attention should be directed both at functions alone and at combinations of functions. For example, it might be important to consider both the attention and guidance functions if two treatments differ in the events designed to direct attention, but not in those designed to provide learning guidance, since the events designed to guide the learner might compensate for any differences related to directing attention. In this case, an aptitude related to attention or selective perception might not be worth investigating.

In summary, it has been suggested that ATI researchers, having already developed or selected the treatments of interest, can select more appropriate aptitude variables by focusing on (a) the nature of the intended learning outcomes, (b) the functions of instruction most relevant to the intended learning outcomes, and (c) those relevant functions that are served by different events in each treatment.

Selecting or Developing Instructional Treatments, Given That Aptitudes Have Already Been Selected

Many researchers, for one reason or another, may have already decided which aptitudes are of interest to them (e.g., state-trait anxiety seems to be popular, both within and outside the realm of ATI research). Their concern might be with discovering the limits of generalizability of the aptitude variables or with the solution of some practical problem, such as

determining the relationship between a measure of achievement motivation and self-paced instruction. The task faced by the researcher who has already decided which aptitudes (s)he wants to study is that of determining the instructional events within the treatment situation. The questions to follow are some of those a researcher needs to ask in order to select or develop instructional treatments that are likely to interact with the selected aptitudes.

1. What psychological processes are related to the selected aptitudes? The intent of this question is to focus the researchers' attention on the systemic nature of psychological variables. Not only must the researcher specify the components and processes of the aptitude variables, but (s)he must also determine the relationships between the aptitudes (as broadly conceived by Cronbach and Snow, 1977) and other psychological processes. Some aptitude variables--age, for example--are not themselves complex, but probably have complex relationships with certain psychological and physiological processes. Other aptitude variables like prior achievement and measures of intellectual or personality functions may be complex themselves and may also have complex relationships with other psychological processes. By making explicit the nature of the aptitudes and their relationship with other psychological processes, the researcher can be more precise in relating aptitudes to potential learning outcomes and instructional treatments.

2. What intended learning outcomes are related to the selected aptitudes? The concern here is with determining the kinds of learning outcomes that are differentially related to the aptitudes being investigated. This determination requires an analysis of the performances necessary to the acquisition of the learning outcomes. On the basis of the learner's performance, inferences

about the psychological processes can be made. Once the nature of each outcome has been analyzed, the outcome-related processes, which are inferred from the learner's performance, can be compared with the psychological processes related to or inherent in the aptitude. For example, the acquisition of a simple motor skill, such as hammering nails, will likely call upon different psychological processes and therefore different aptitudes or levels of an aptitude than would the acquisition of an intellectual skill, such as determining the types of nails that are appropriate for different construction tasks. Once the researcher has determined possible learning outcomes within various content domains, (s)he is ready to select or develop the instructional treatments.

3. What treatment functions are relevant to the selected aptitudes? Assuming that the aptitudes of interest to the researcher have already been identified, certain instructional functions will be more relevant than others. In a study designed to examine an aptitude related to memory functioning, for example, the function of enhancing retention may be more important than the function of directing attention. The determination of the learning outcomes will also suggest which functions are more important than others. For example, in a study using problem-solving in quantum mechanics as an outcome and the level of prior achievement as an aptitude, the function of recalling prerequisite skills and knowledge might be more important than the function of activating motivation; the assumption in such a case is that, generally, only highly motivated people study quantum mechanics. After the most relevant functions have been identified, the next step is to explore various instructional events that have potential for activating different psychological processes related to the aptitudes being investigated.

4. What kinds of instructional events are suggested by the selected aptitudes? This question focuses the researcher's attention on the problem of selecting or developing different instructional events for each treatment. The event should focus on the most relevant instructional functions and should be designed to enhance, suppress, or in some way accommodate the psychological processes related to the aptitudes under study. If informing the learner of the objective had been found to be a relevant function in a study exploring verbal aptitude, the events related to this function could be varied by altering the reading level of the objectives in each treatment. Or, in a study involving internal vs. external motivation, where eliciting performance and providing feedback had been identified as an important function, the nature of the feedback might be varied. In one treatment the teacher might provide frequent and timely feedback, while in another treatment the only feedback might be that which results as a natural consequence of the performance. By considering the psychological processes related to each aptitude and the relevant functions of instruction, the researcher should be able to select or develop instructional events that maximize the probability of finding aptitude-treatment interactions.

In summary, this section has addressed the problem of selecting or developing instructional treatments, given that aptitudes have already been selected. The following questions were suggested as helpful to the researcher in solving this problem:

1. What psychological processes are related to the selected aptitudes?
2. What intended learning outcomes are related to the selected aptitudes?
3. What treatment functions are relevant to the selected aptitudes?
4. What kinds of instructional events are suggested by the selected aptitudes?

Benefits for ATI Research

An approach to ATI in which the instructional treatments are analyzed in terms of their functions can further the progress of such research in several ways. First, examining the treatment functions can help ATI researchers focus on the nature of the psychological processes called upon by the treatment situation. Second, the approach can aid the progress of ATI research by narrowing the field of relevant aptitudes to include in a study. And third, this approach can facilitate the determination of relevant dependent or outcome variables. The general effect of focusing on the functions of instruction should be to enhance the ecological validity of ATI research. Following are illustrations of the three ways in which the functions approach can further the progress of ATI research.

Focus on the nature of psychological processes. The approach described in this paper, because it asks the ATI researcher to consider the various functions served by each instructional treatment, forces the researcher to focus on the psychological processes related to the components of the treatments that are designed to serve each function. For example, two treatments as apparently different from each other as televised lecture and programmed instruction might not differ substantially in the functions they serve or the way they serve them. For the particular content, intended learning outcomes, and population of interest, both treatments might be equally effective in motivating students, directing their attention to relevant aspects of the content, and so on. By asking which components of the treatments serve which functions, the researcher can then examine potential aptitude variables to determine whether there is a plausible link between the internal processes of the learner and the external conditions of learning (the treatment components).

Narrowing the field of relevant aptitudes. The second way in which a focus on the functions of instructional treatments can aid the progress of ATI research is by narrowing the field of relevant aptitude variables to be examined in a given study. If one looks only at the individual and the intended learning outcomes, many aptitudes may suggest themselves, but only a few might be relevant in terms of the functions of the instructional treatments and their differential ability to serve these functions. Using again the example of programmed instruction vs. televised lecture, and this time the function of providing learning guidance, both treatments might handle this function equally well for all learners. Thus, an advantage that programmed instruction might have given certain learners--because of increased opportunities to practice--would have been wiped out. If an aptitude related to a need for practice had been under study, a significant interaction would probably not have been found. On the surface, a particular aptitude may seem very important, but, when considered in relation to the various functions to be served by the treatments, its importance may be diminished. Thus, the interrelationships among aptitudes and between aptitudes and treatment functions need to be considered in order to avoid examining irrelevant aptitudes.

Determining relevant outcomes. And finally, the third way in which the functions approach can aid ATI research is by facilitating the determination of relevant dependent or outcome variables. The importance of appropriate outcome variables is obvious, but what constitutes an appropriate outcome or set of outcomes is not as obvious. ATI researchers have often focused on a single cognitive outcome as measured by a variety of tests that have been developed by teachers, researchers, or commercial test developers.

However, the complexities of the learning environment suggest that many outcomes, both cognitive and noncognitive, might be relevant. By analyzing the instructional treatments in terms of their functions, identification of the most relevant outcome variables can be facilitated. For example, the function of providing learning guidance suggests certain outcomes, such as the kind of errors made under different conditions of presentation of what is to be learned, while the function of promoting transfer suggests other outcomes (e.g., ability to perform the skills learned in new or different situations or facility in learning higher-order intellectual skills). The kind of outcomes suggested by examining the functions of instruction not only can help provide a more complete picture of what is being learned in a given situation, but can also provide valuable information regarding learning and instructional processes. Using this process information, the researcher can determine exactly what went on in the learning situation and can judge the extent to which the learners actually participated in the treatment.

It should be apparent from the above that examining the functions of instruction can help ATI researchers design complex, real-life studies, which have an increased opportunity of providing ecologically valid results. Also, the use of process information can facilitate the interpretation of negative results when these are found.

SUMMARY

This paper has addressed a persistent problem in ATI research--the need for a better conceptualization of instructional treatments. The two concerns discussed herein are seen as important in the analysis of instructional treatments. These concerns are (a) the importance of considering the

psychological processes called upon by the instructional treatment, and (b) the ecological validity of the treatment. Then, a framework for analyzing treatments in terms of their functions was presented. Eight functions of instruction were suggested as providing a relatively complete description of the instructional situation. These functions were discussed in relation to questions a researcher might ask under each of two conditions: (a) when selecting aptitudes, given that treatments have already been selected or (b) when selecting or developing treatments, given that aptitudes have been decided upon. The final section of the paper addressed the benefits that ATI research might derive from studies that examine the functions of instruction. It was suggested that this approach would help ATI researchers (a) focus on the nature of the psychological processes called upon in the treatment situation, (b) narrow the field of relevant aptitudes, and (c) determine relevant outcome variables.

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